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Australian Government
Department of Defence
Defence Science and Technology Group

Physical Mechanisms for Blast Mitigation using Fluid Containers: Effect of Container Geometry

Huon Bornstein
DST Group & RMIT University (Australia)

PhD Supervisors: Adrian Mouritz and Shannon Ryan

ISB 29, Edinburgh, Scotland
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RMIT UNIVERSITY

DST GROUP Science and Technology for Safeguarding Australia

Previous Work – ISB 28 (Atlanta)

- Two different vehicle responses that cause injury are assessed
- Global Motion (initial velocity) and Localised Deformation

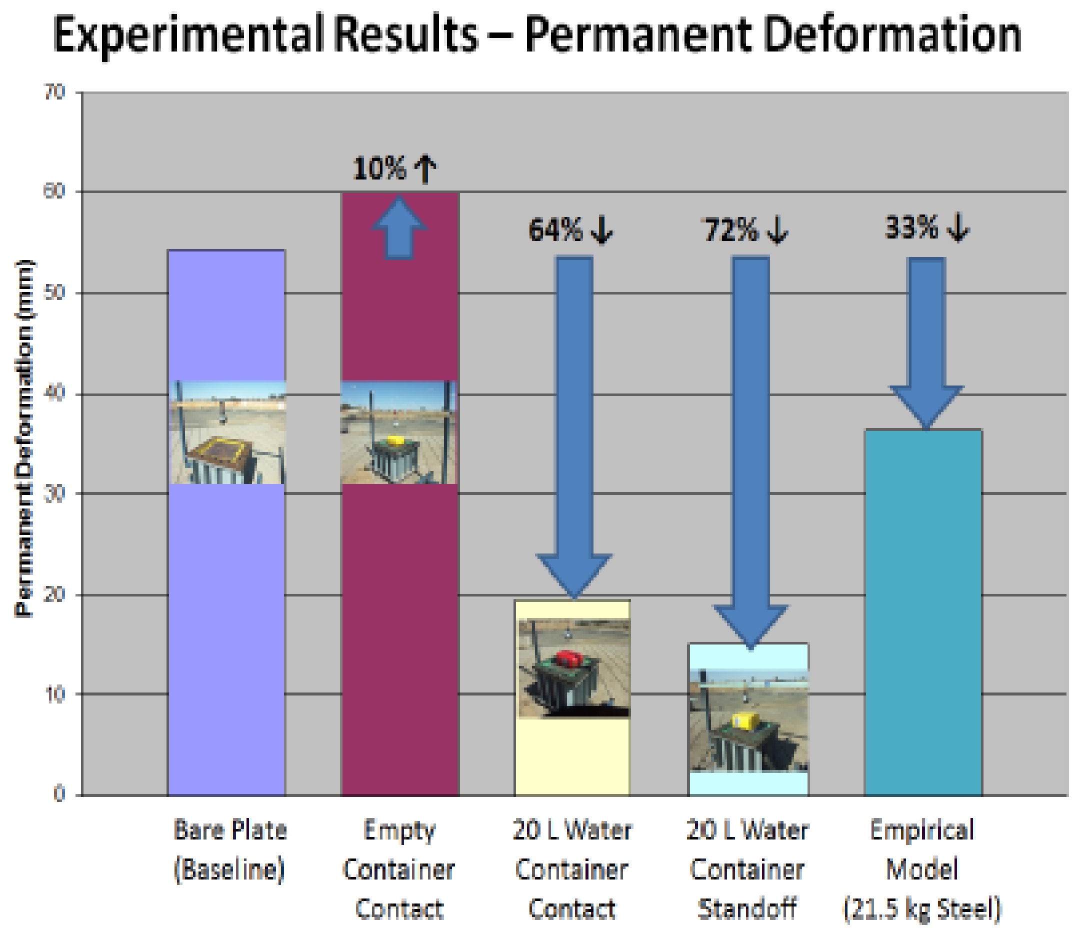
Global Motion Setup

Deformation Setup

Described in Bornstein et al., Evaluation of the blast mitigating effects of fluid containers, JImpactEng, Vol. 75.

Previous Work – ISB 28 (Atlanta)

- ~65% Mitigation from water container
- Mitigation appears better than steel
- Water can be very beneficial for reducing deformation



Described in Bornstein et al., Evaluation of the blast mitigating effects of fluid containers, JImpactEng, Vol. 75.

Experimental Test Setup

- Explosion Bulge Die Tests
- 5.06 kg PE4 charge
- 600 mm standoff
- Base plate was 10 mm steel
- Laser displacement transducer used on most tests
- All tests repeated (some without laser to ensure validity of measurement)

Water Container

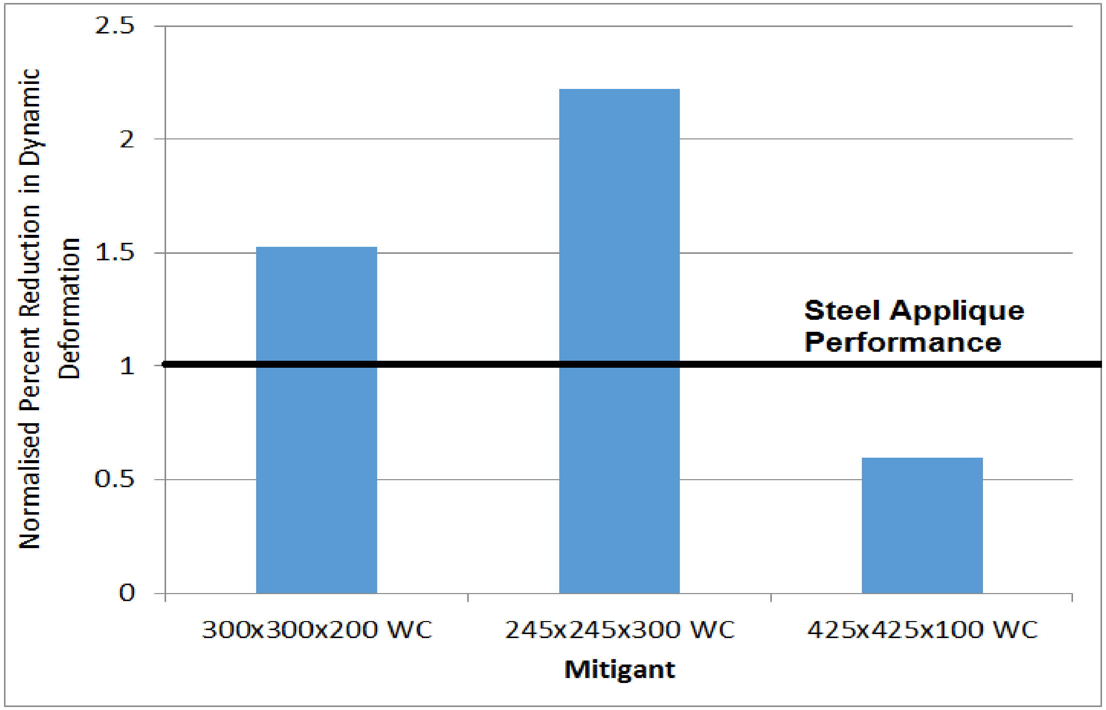
Water Container

Steel Applique

Water Box

Results to be published in Impact Engineering (In Review)

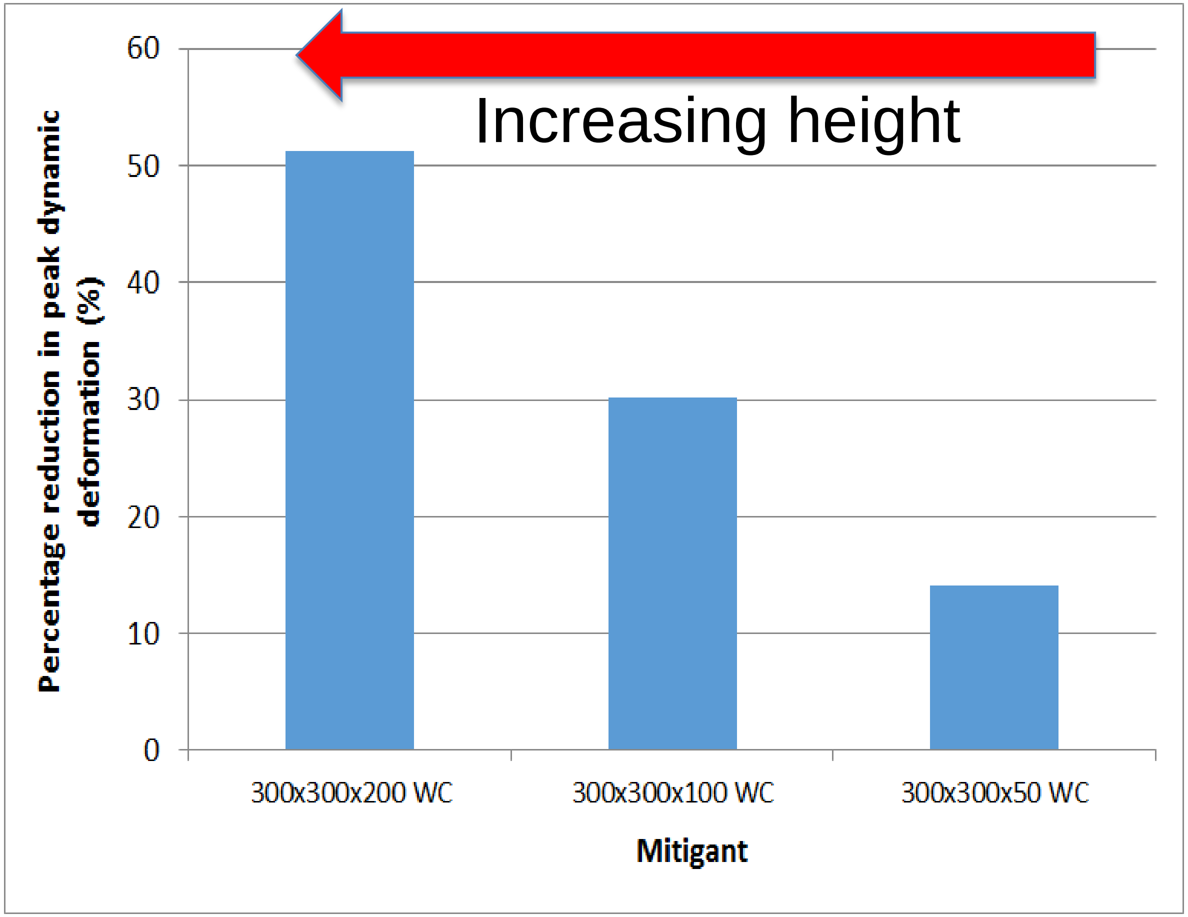
Effect of Container Geometry (Constant Volume)



- Water containers outperformed equivalent areal density steel panels for 2/3 test conditions.

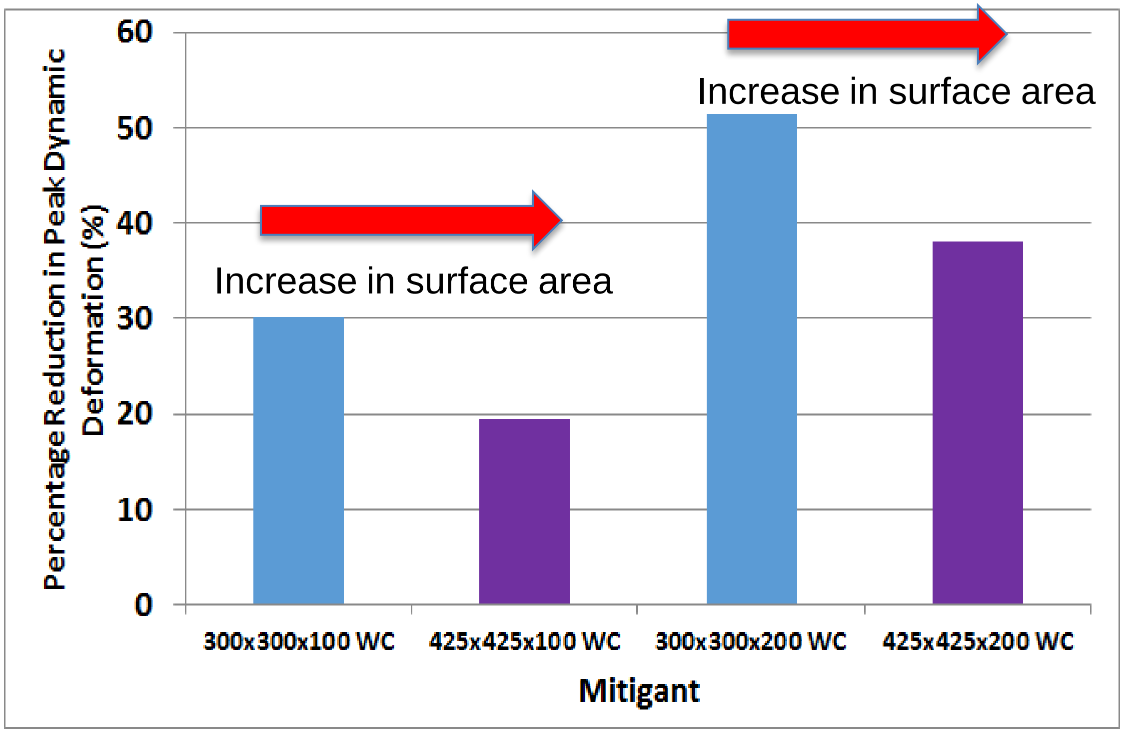
- Geometry of fluid was very important. Geometry of steel had minimal effect on mitigation. (Not shown)

Effect of Container Height (Constant Surface Area)



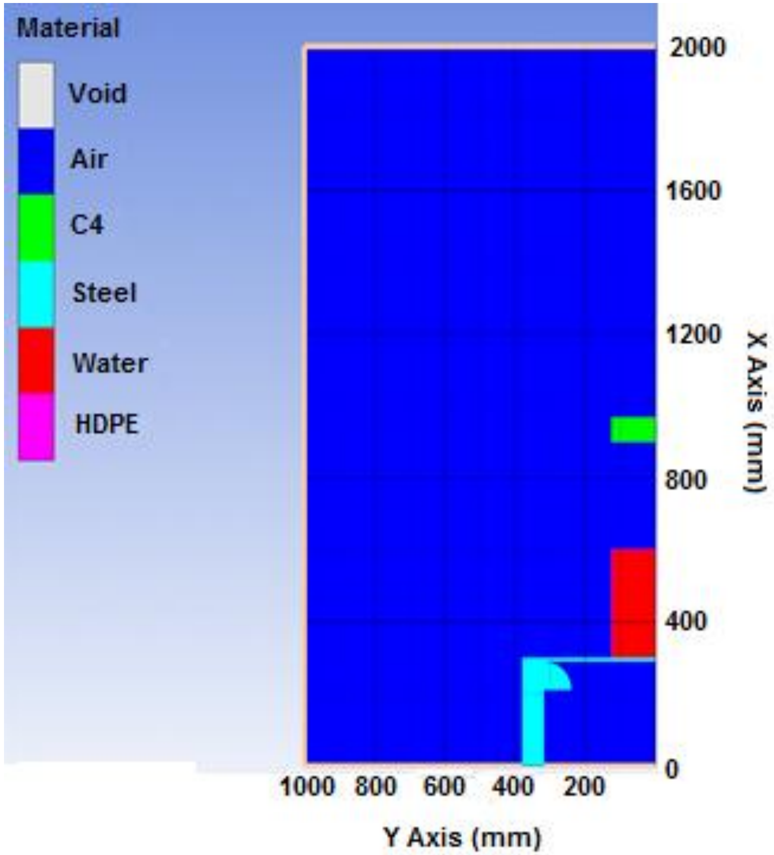
- Increase in height (fluid volume) results in enhanced mitigation.

Effect of Container Surface Area (Constant Height)



- Unusual result
- Increase in surface area (volume) results in less mitigation.
- Can we model the phenomenon?

Numerical Model Setup and Results

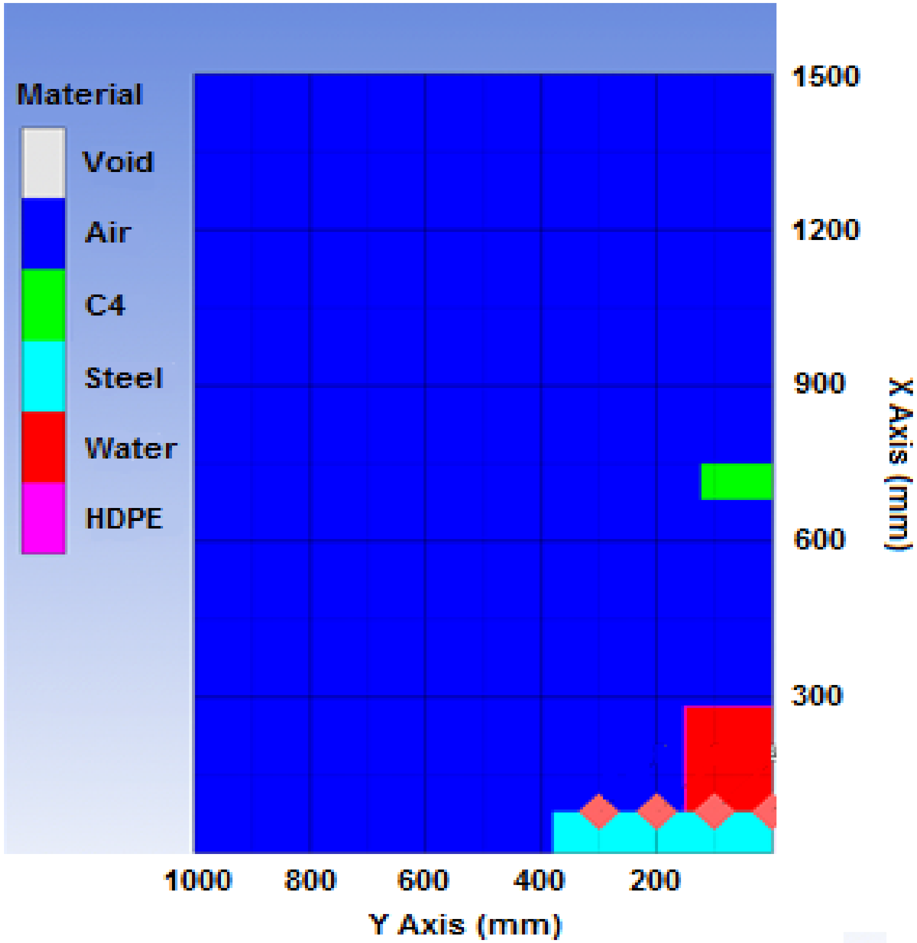


- 2D axisymmetric setup of experiment used following mesh refinement
- 1 mm x 1 mm element size
- All materials from literature or characterisation tests

- Model matched the baseline result (113 mm exp vs 114 mm model).

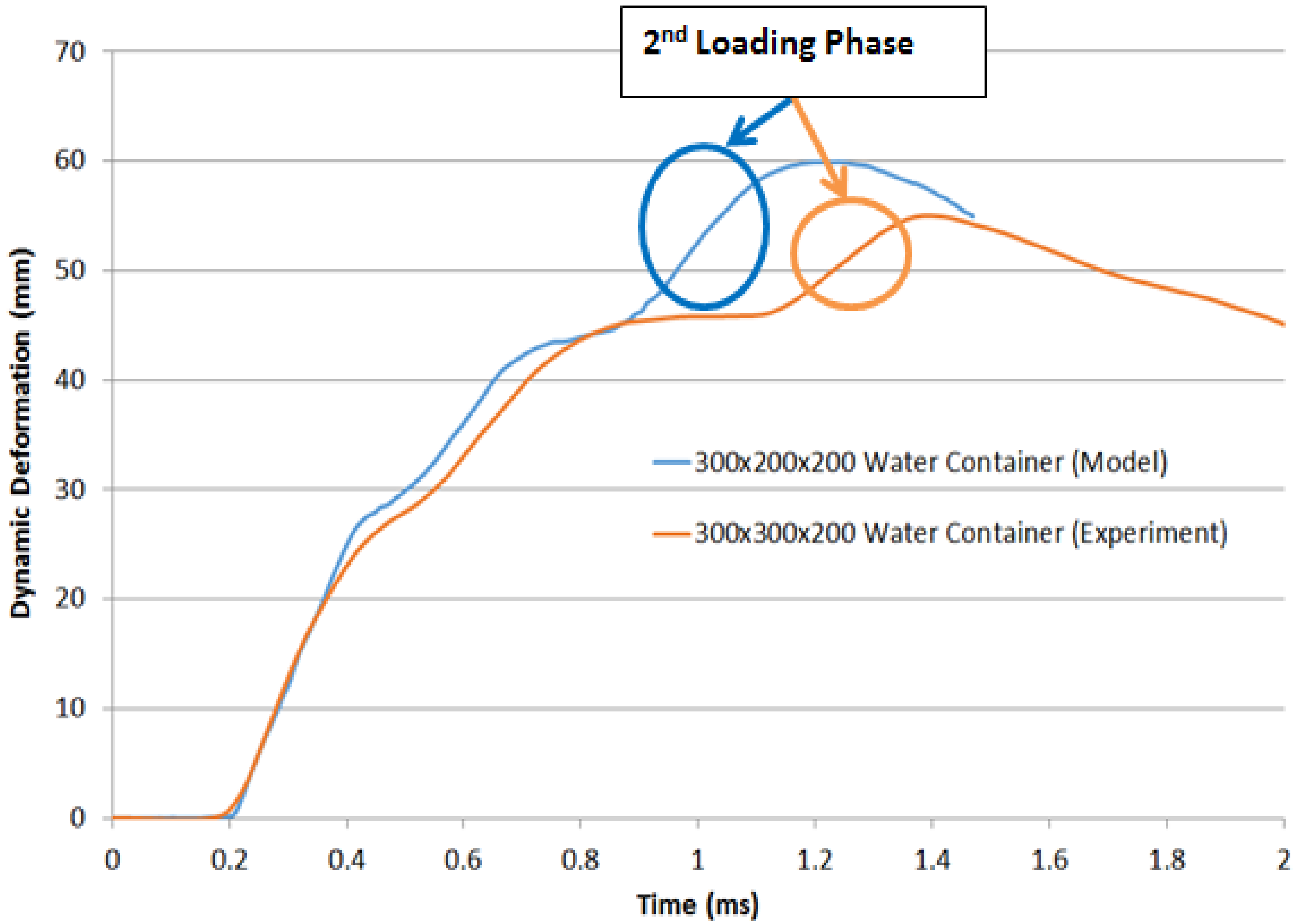
- Models predicted the deformation within 12% for all test conditions.

Thick Plate Model Setup – Physical Mechanisms

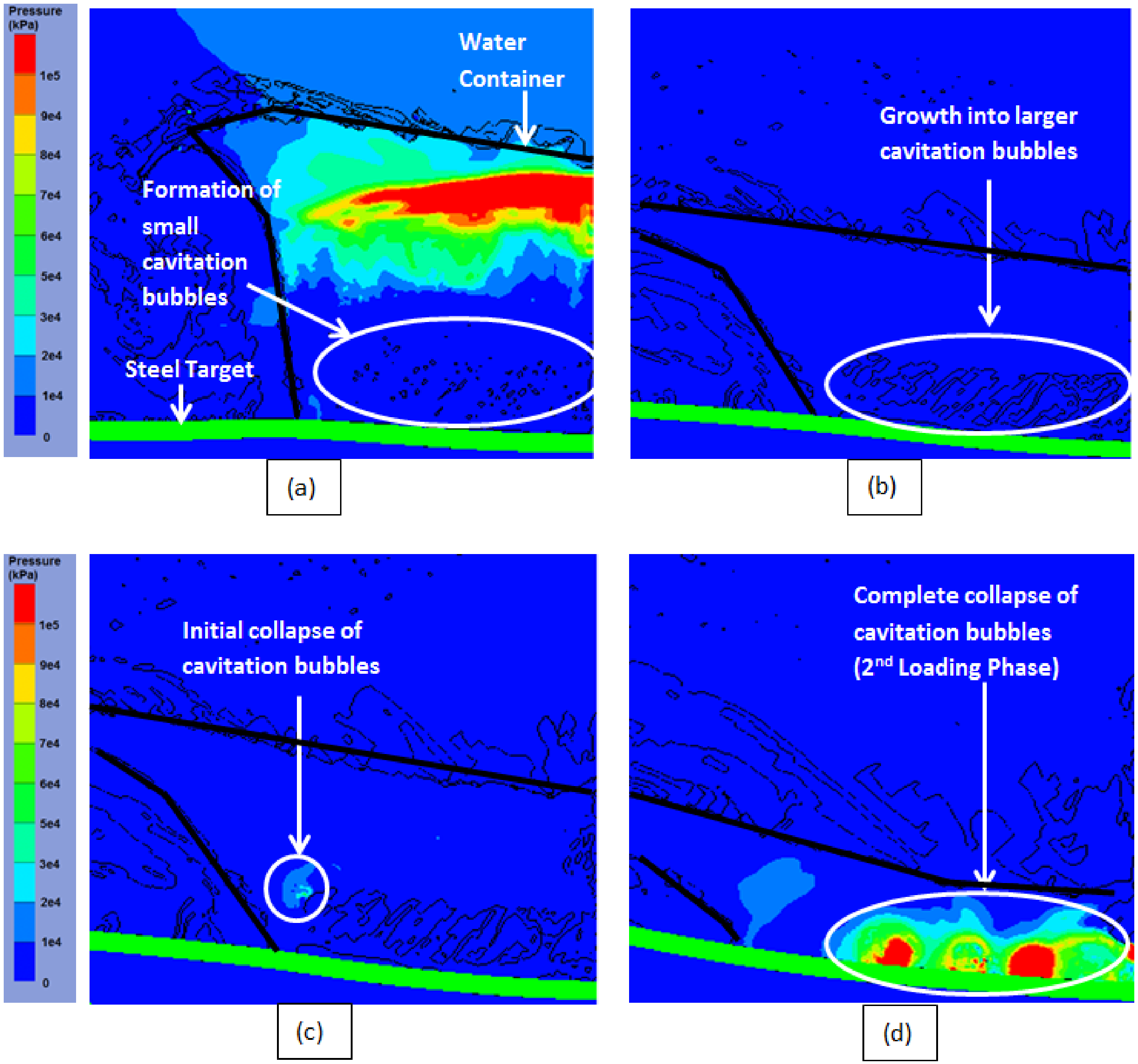


- 2D axisymmetric setup of thick plate (EBD size)
- 1 mm x 1 mm element size
- All materials from literature or characterisation tests
- Pressure gauges used to determine spatial distribution of the loading

Physical Mechanisms – 2nd Loading Phase



Physical Mechanisms - Cavitation



a) Formation of small cavitation bubbles at 0.280 ms

b) Growth into larger cavitation bubbles at 0.500 ms

c) Initial collapse of cavitation bubbles at 0.550 ms

d) Complete collapse of cavitation bubbles at 0.865 ms showing a 2nd loading phase on the target.

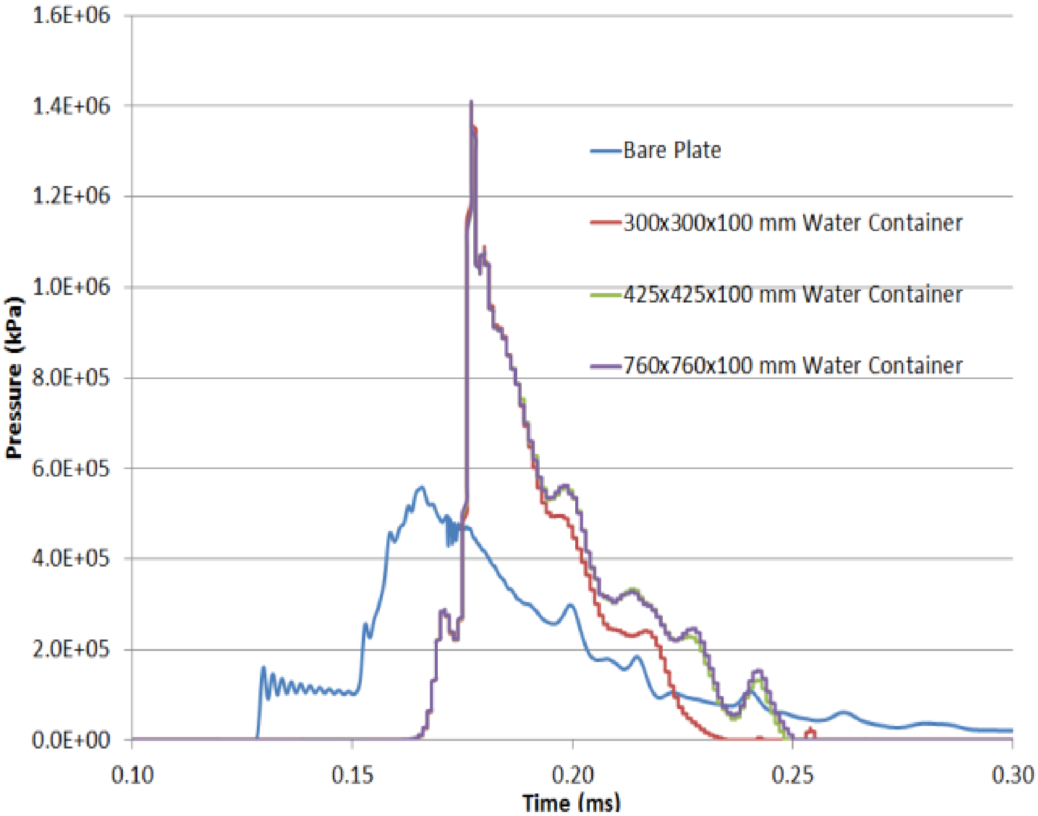
Physical Mechanisms - Evaporation

- Lots of discussion in the literature about evaporation being responsible for blast mitigation with water.

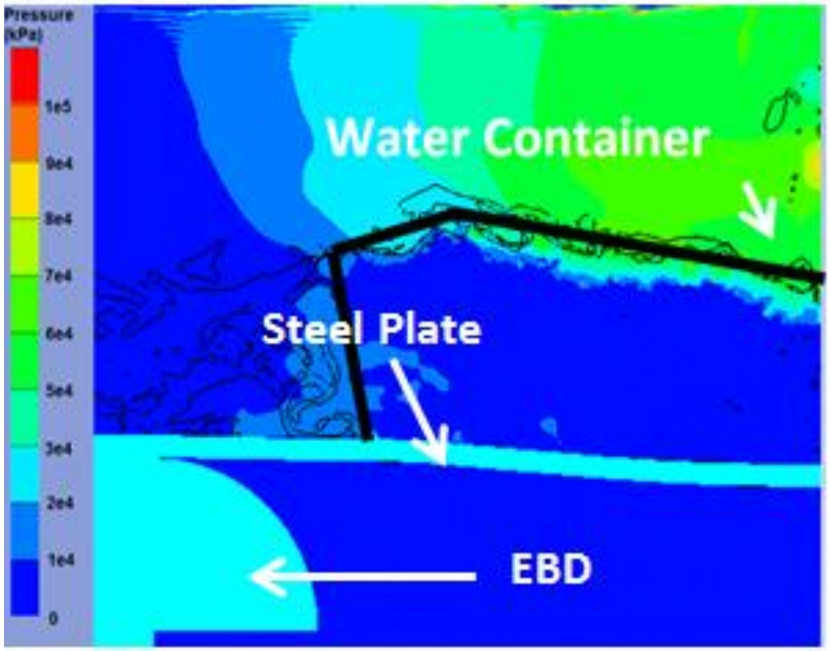
- Grujicic et al. performed analysis for bulk water surrounding an explosive using equations for water breakup and evaporation from the literature. Found 0.5-2 ms for breakup of water droplets and further 3-5 ms to evaporate the water droplets.

- As previously discussed in our first journal paper, the timeframe of the loading appears to be far too short for this to be a mitigation mechanism for this scenario.

Physical Mechanisms – Momentum Extraction

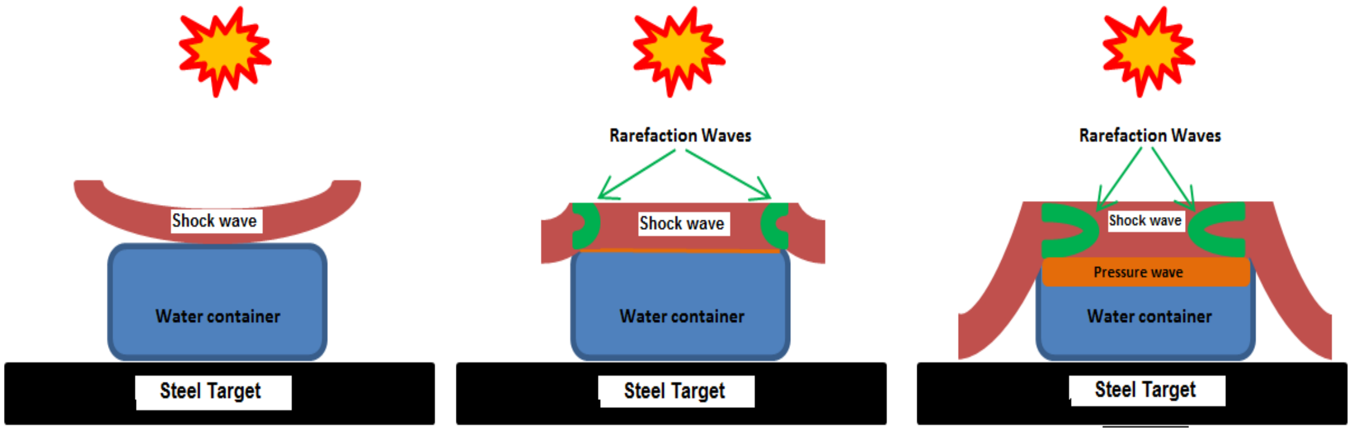


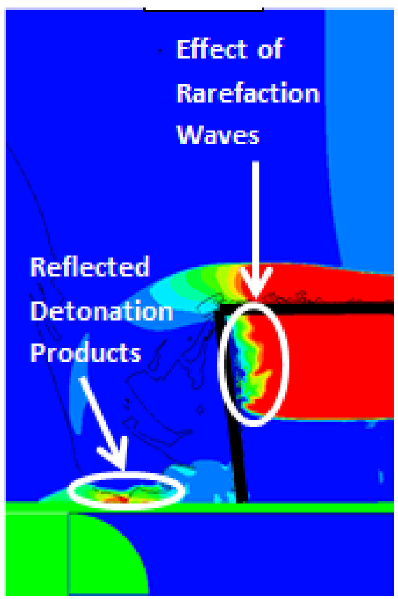
425x425x100 mm water container



Simulation time: 0.255 ms

Physical Mechanisms – Clearing (rarefaction waves)

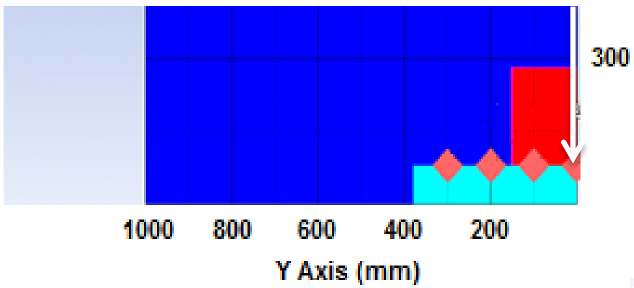


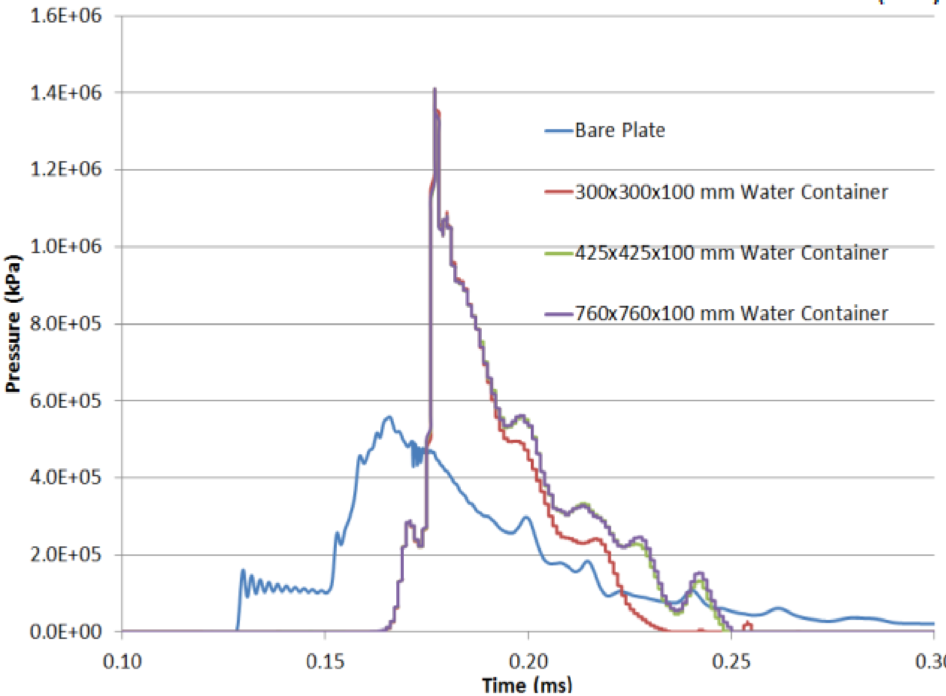


300x300x200 mm
Water Container Simulation

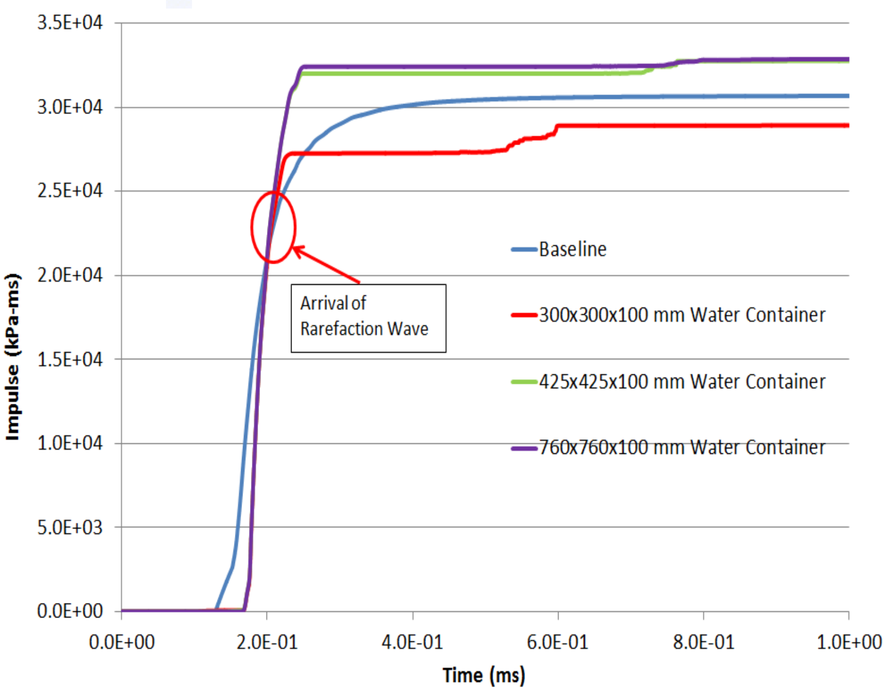
Physical Mechanisms – Rarefaction Waves

At centreline





Pressure - Time

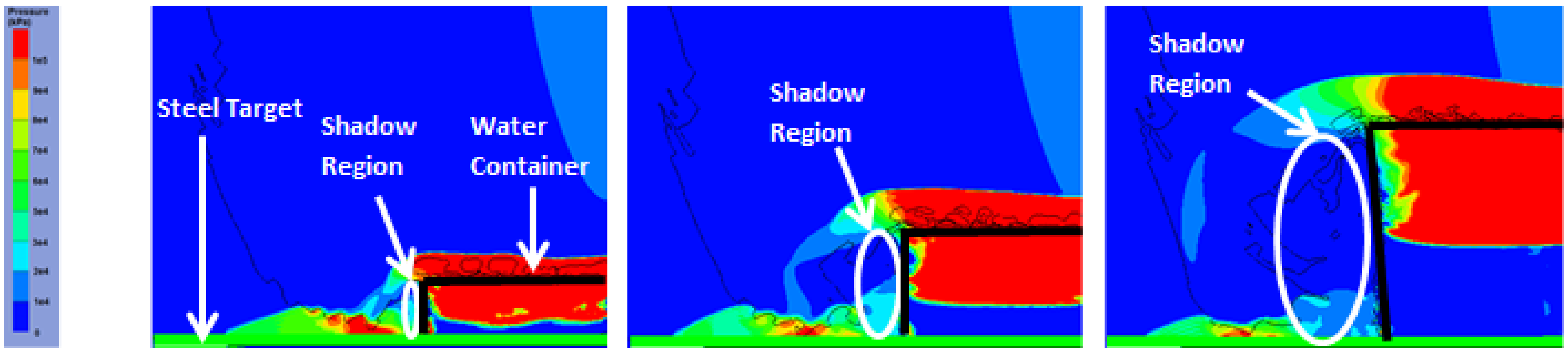


Impulse - Time

Physical Mechanisms – Shadowing (Det Products)

- The detonation products are deflected by the container.

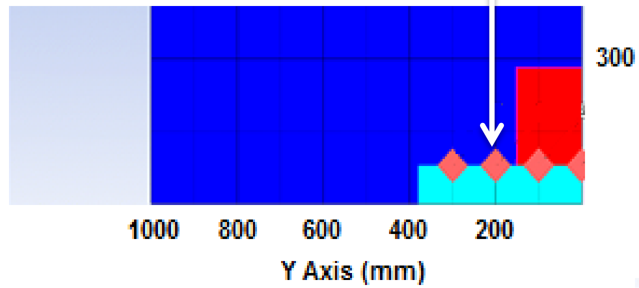
- The height of the container affects the strength of the loading from the detonation products and the size of the shadow region (low pressure) at the edge of the container.

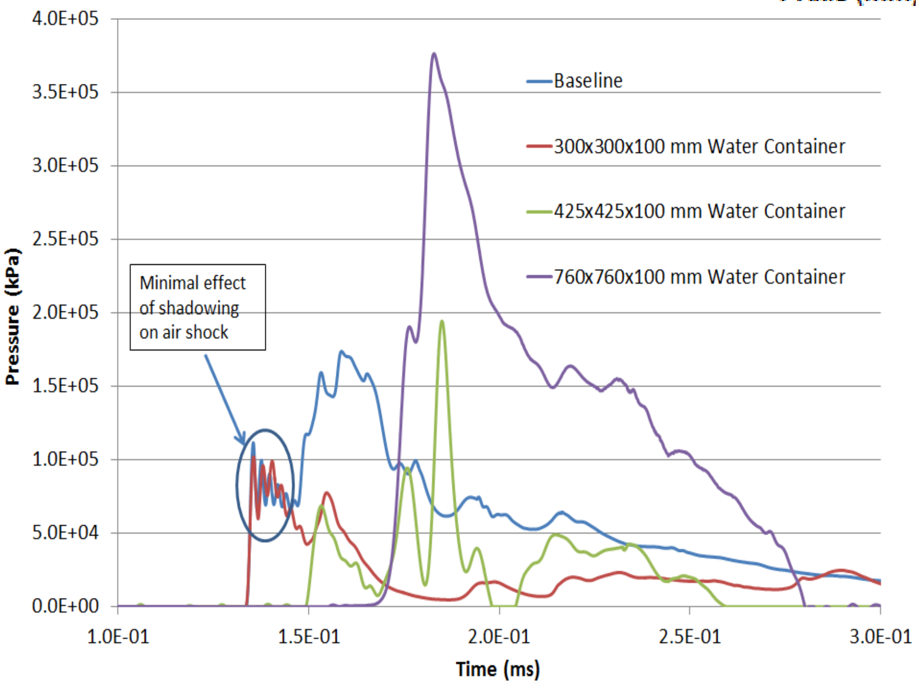


300x300x50 mm Water Container | 300x300x100 mm Water Container | 300x300x200 mm Water Container

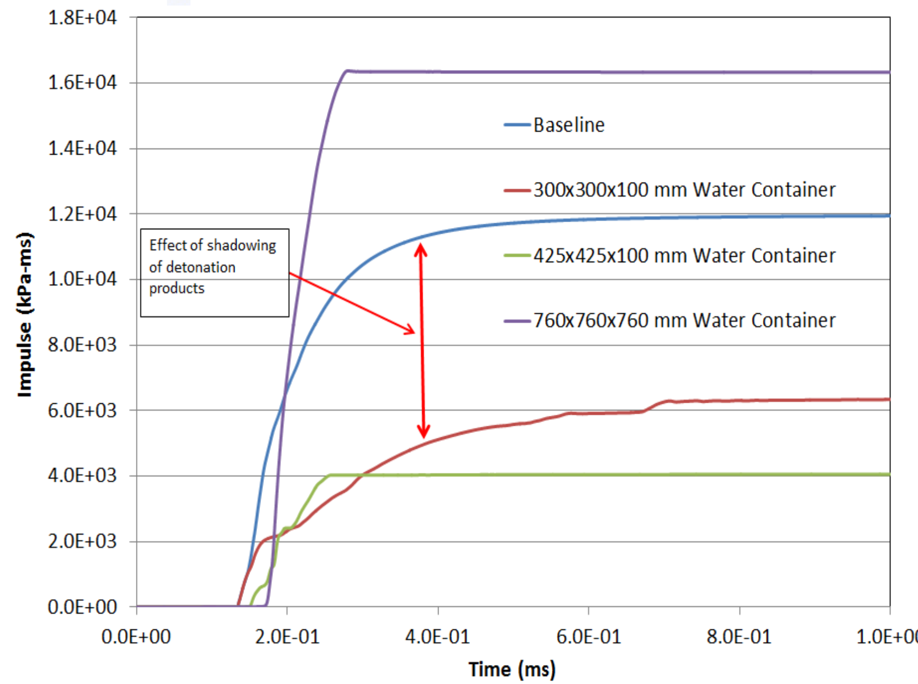
Physical Mechanisms – Shadowing

200 mm from centreline





Pressure - Time



Impulse - Time

Conclusions

- The key mitigation mechanisms are:

  1. Shadowing

  2. Rarefaction waves

- Further work is required on cavitation

- Water filled containers can significantly outperform steel on an areal density basis if the geometry is selected appropriately.

- Fluid filled containers could be used to provide additional protection to armoured vehicles.

Acknowledgments

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Questions